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(54) Data transmission

(57) In order to enable credit account details to be transmitted from a credit card payphone in a cellular radio telecommunications system, the data digits representing the account details are encoded using an algebraic parity check code and transmitted along with the checksum digit and the check digit by means of a DTMF demodulator. When three check digits are used then a burst of three missing digits, which may occur as the result of the handoff of the call during transmission of the data, can be corrected.

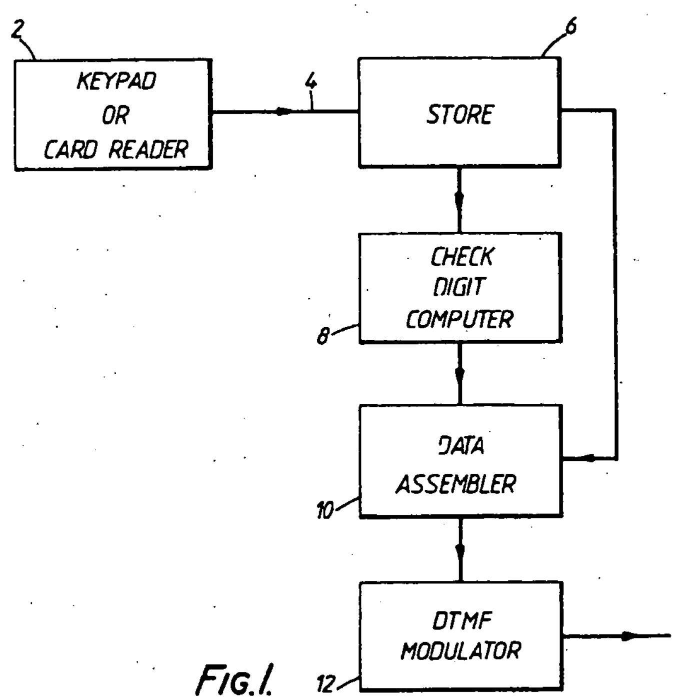

FIG. 1.

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The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1982.

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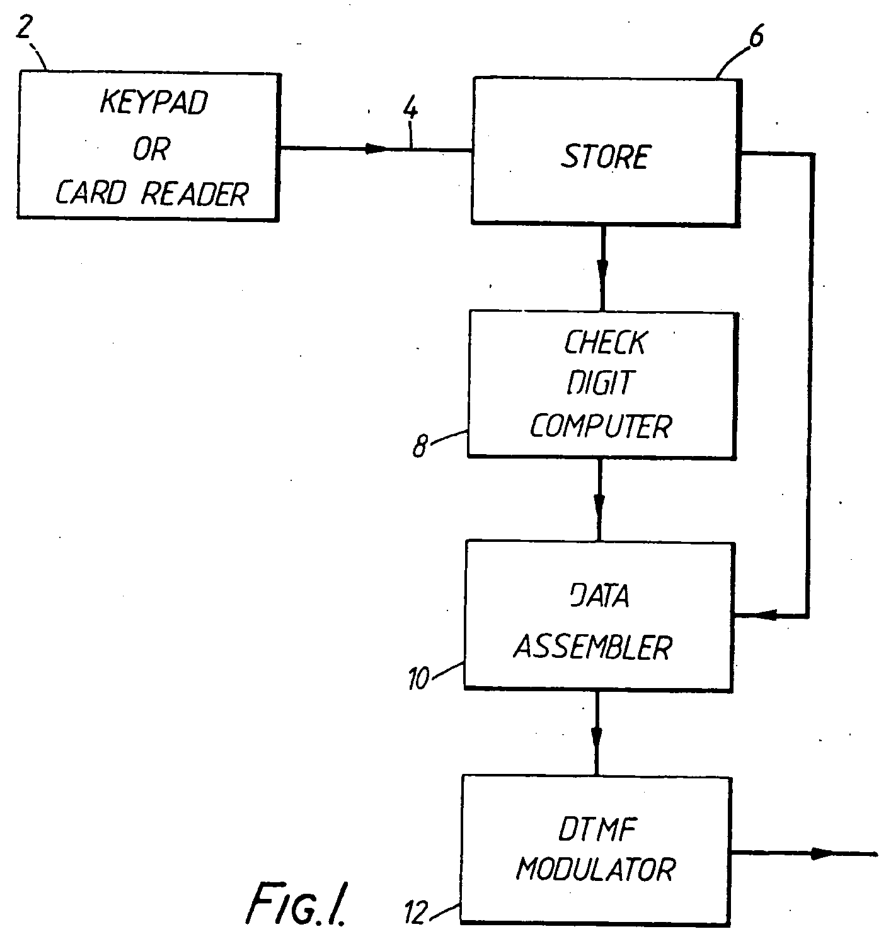

FIG.1.

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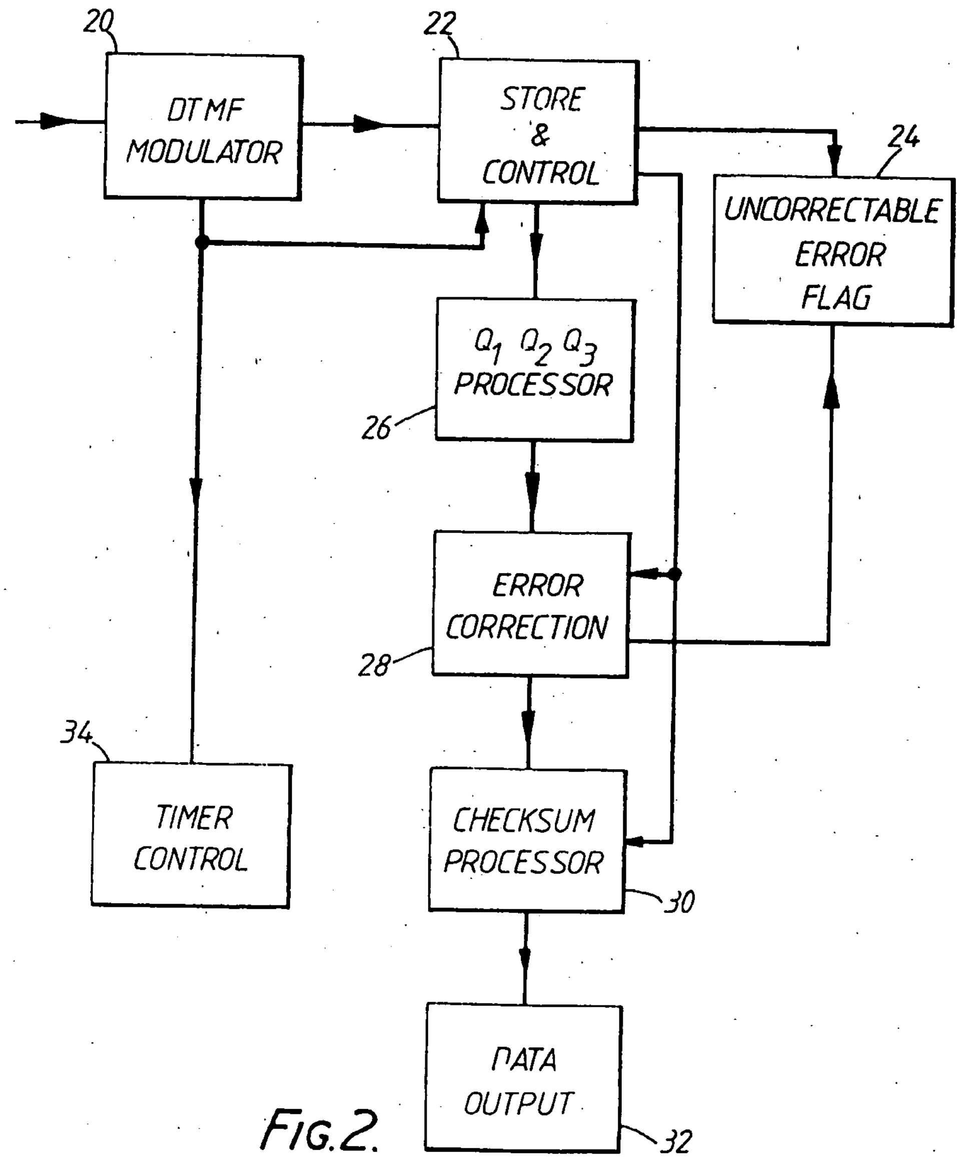

FIG.2.

SPECIFICATION

Data transmission

The present invention relates to a method and apparatus for data transmission using DTMF with a forward error correcting code and, more particularly, to credit card payphones for use on a cellular radio radio telephone system which are adapted to transmit credit card numbers over a telephone link.

In order to enable telephone calls to be made and the charge credited to a credit card account, it is necessary that account details, typically the credit card number should be transmitted to the exchange or some other central station so that the cost of the subsequent call can be debited to the caller's credit card account.

Credit card payphones are already available for use on conventional landline telephone systems. One such credit card payphone uses a card reader to read the credit card account number and this is then transmitted as a sequence of hexademical digits along the telephone line to the exchange by means of dual tone multifrequency modulation (DTMF, also known as Touchtone in the U.S.A.)

It would be particularly advantageous to provide credit card payphones for use on a cellular radio telephone system as this would allow public telephones to be made available to taxi, train, ferry and coach users. In order to allow credit cards to be used for making telephone calls using a cellular radio system, it is also necessary that the details of the credit card account be transmitted to a central station. However, when using a cellular radio telephone link for transmitting data, there is a greater probability that some data will be lost during transmission than in the case of the use of a landline telephone link. This arises because handoff of the call may take place from one base station to another during transmission of the data. During such a handoff, there is typically a very short break in communications and this can cause one or more digits to be lost. Using commerically available DTMF modulating and demodulating devices it is found that handoff typically causes three digits of the data to be lost.

Cellular radio telephone links may also be subject to multipath fading effects which can also cause the loss of one or more digits. Therefore, if a conventional credit card payphone is used on a cellular radio system, there is a high probability that the credit card details will not be received accurately and, therefore, the caller will have to try and initiate the credit card call once again.

In order to overcome the above-mentioned difficulties, the present invention is directed to solving the technical problem of providing a credit card payphone for use on a cellular radio telephone system, and a method of transmitting data which is suitable for use with such a payphone.

The present invention accordingly provides a credit card payphone for use in a cellular radio telecommunications system, comprising a cellular radio telephone, means for inputting details of a caller's credit card account in the form of a series of data digits, means for computing a checksum comprising k digits representing the sum of the data digits modulo n^k, and at least three further check digits, each check digits being computed as the complement of the sum of a subset of the data digits and the digit(s) of the checksum digit modulo n, each data digit and digit of the checksum being included in at least one sum, and means for transmitting a sequence of digits including said data digits, said checksum and said at least three check digits using a DTMF modulator adapted to transmit n different frequency combinations.

Such a credit card payphone will be used in conjunction with a receiver at the central station, which receiver comprises a DTMF demodulator for decoding the received digits, means for recognising and flagging missing digits, means for computing from said received digits at least three reference digits, where each reference digit is the complement modulo n of the sum of a respective check digit and the sum of the received digits corresponding to the digits used to compute said check digit, said reference digits being calculated using a zero in place of any missing digit, means for using said reference digits to correct no more than one missing digit in the sum from which each reference digit is computed, and means for outputting the received data digits including any corrected data digits if and only there is no more than one missing digit in the sum for each reference digit and the received or corrected checksum corresponds to the sum of the data digits modulo n^k.

By using such an algebraic parity check code using at least four non-data digits including one digit for the checksum, it is possible to transmit the data digits, which typically represent the credit card account number, accurately and yet identify any uncorrectable errors that may occur. Three check digits are preferably used since it has been found that a burst error of three digits duration is the maximum which normally occurs during a handoff of the cellular radio telephone call from one base station to another. However, if the data rate of the DTMF modulator is increased, in may be necessary to include more check digits to the maximum number of digits which may be missed during a handoff. Greater security can be provided by using two or more

digits for transmitting the checksum.

Preferably each check digit is computed as the complement of the sum of every mth digit of a sequence made up of the digit(s) of the checksum and the data digits, where m equals the number of check digits to be computed.

In a preferred embodiment of the telephone a predetermined header sequence of digits is transmitted prior to transmission of the data digits, check digits and checksum. This predetermined sequence preferably comprises digits which cannot appear as data digits so that the header can be readily distinguished by the receiver from the following data digits. The header is then used by the receiver to recognise the start of the transmission or that a transmission has started and, therefore, identify the data digits so that the transmitted data can readily be decoded even if the receiver does not accurately recognise the start of data transmission.

Preferably the last digit of the sequence is at least one predetermined final digit which can be a digit which cannot occur as a data digit. This allows the end of the sequence to be recognised.

The present invention further provides a method of transmitting data for use in a telecommunications system, using a DTMF modulator capable of transmitting n distinct digits, the method comprises processing a block of data digits to compute a checksum and a plurality of check digits, where each check digit is computed as the complement of the modulo n sum of a mutually exclusive set of the data digits and digit(s) of the checksum, transmitting the data digits, the checksum and the check digits in a known predetermined sequence via a DTMF modulator.

Data transmitted as defined above is received by demodulating each successive received digit of the sequence and, when at least the checksum and all the check digits have been received, computing a plurality of reference digits, each reference digit being the complement modulo n of the sum of a respective check digit and the received digits corresponding to the data digits and/or digits of the checksum used to compute said check digit, flagging an uncorrectable error if the sum for any said reference digit includes more than one missing digit, setting any one missing digit in any said reference digit sum to said reference digit, and outputting the received data digits when the received checksum (if necessary after correction) corresponds to the sum of the received data digits.

This transmission method can also be used for other applications where small volumes of data are to be sent on a noisy telephone channel, for example transaction authorisation information.

A cellular radio credit card payphone and associated receiver for use in a central station, in accordance with the invention, together with a method of transmitting and receiving data in a cellular radio telecommunications system, will now be described, by way of example only, with reference to the accompanying diagrammatic drawings, in which:

Figure 1 is a block diagram of the apparatus for transmitting data in a cellular radio credit card payphone; and

Figure 2 is a block diagram of the data receiver apparatus for use in a central station.

The modulation system used for transmitting the credit card account details in the system to be described is dual tone multifrequency keying (DTMF or Touchtone in the U.S.A).

This is a form of modulation where, for example, 16 distinct digits can be transmitted on a telephone line adapted for voice communication. Each distinct digit is transmitted by sending a unique pair of frequencies or tones simultaneously to line. Each pair is made up of a frequency selected from a low frequency set and a frequency selected from a high frequency set. A DTMF modulator conforming with international standard CCITT Q23 can transmit 16 distinct digits by transmitting one tone selected from a first group of frequencies: 697, 770, 852 and 941 Hz, and a second tone selected from a second group of frequencies: 1209, 1336, 1477 and 1633 Hz. In the present application each of the 16 possible digits is used to represent a distinct one of the hexadecimal digits 0 to F. Modulators for converting input hexadecimal digits into the necessary multifrequency output are readily available commercially. Because the transmitted tones have frequencies within the normal voice bandwidth, there is no need to modify the performance of the telecommunications link for used with such a data transmission technique.

The credit card payphone of the present invention is a conventional cellular radio telephone together with apparatus for transmitting data as illustrated in Fig. 1.

A keypad or card reader 2 is used to enter or read the account details, for example the credit card number, from a credit card. These account details will be in the form of a series of decimal digits. For the purposes of the present application, these decimal digits are each considered as a corresponding hexadecimal data digit. Thus no data digit will have any of the hexadecimal values A to F. These data digits are fed along line 4 to a store 6, for example a shift register. A check digit computer accesses the store 6 and produces a checksum and three check digits. The checksum can be computed as more than one digit for greater accuracy. If only one digit is required as in the present embodiment it is computed as the sum of the data digits modulo 16. If k digits are to be computed the sum is taken modulo n^k.

A data assembler 10 assembles a block of data for transmission which is formed from the

data digit, the digit(s) of the checksum and the check digits arranged in a predetermined format. The data assembler 10 may also add a fixed preamble which is made up of a known predetermined subset of the hexadecimal digits A to F. Where a preamble is used the data is assembled so that the preamble is followed by a sequence of data digits so that the end of the preamble and the start of information transmission can readily be identified by the receiver. The data assembler 10 may also add a predetermined final digit to identify the end of the sequence. This is preferably one of the hexadecimal digits A to F. A final marker sequence similar to the preamble could also be used. The data assembler 10 assembles blocks of data which contain up to, for example, 50 data digits. If there are less than 50 data digits to be transmitted, the unused digits are set to zero. This enables variable length transmissions to be sent because some credit cards may use account details comprising more data digits than others. The 'zeroes' are not sent but are regarded as equivalent to no transmission. The assembled data is then passed to the DTMF modulator 12 which passes corresponding pairs of frequencies to the telephone line for each digit to be transmitted at a fixed rate. The use of a fixed rate allows missing digits to be acted at the receiver by timing.

The apparatus required at the receiver for restoring the transmitted block of data is shown in Fig. 2. The incoming signal on the telephone line is demodulated by a DTMF demodulated 20 which outputs a sequence of hexadecimal digits to a store 22. Control means associated with the store allow the first received hexademical digit to be recognised as the start of a new transmission. If a preamble is used then the control means match the first hexademical digit received with its expected position within the preamble so that the control means can flag the start position of the block of data digits, checksum and check digits being transmitted.

The control means associated with the store is also able to identify any missing digits, which were not properly demodulated by the DTMF demodulator 20. This may be due to extraneous noise on the telephone link, a handoff of the telephone call from one base station to another, or multipath fading effects. The missing digits are set to zero for the purposes of the following computations and flagged. If a sequence of greater than 3 missing digits is received then an uncorrectable error flag message is sent to processor 24, which may request retransmission of the entire sequence. At the end of the received sequence no further transmission will be found so signalling the end of the block.

Once a sequence of data digits, which is sufficiently large to include the predetermined positions of the checksum and the three check digits, has been received a processor 26 computes the reference digits from the store contents excluding any preamble digits. An error correction processor 28 associated with the reference digit processor 26 is then able to correct the missing digits or identify that there is an uncorrectable error in the transmission, in which case an uncorrectable error flag message is sent to processor 24 which may request retransmission of the entire sequence.

The corrected sequence of digits is then passed to a checksum processor 30, which compares the received value of the checksum digit with the sum of the data digits so far received. If this value is zero, and other criteria are met indicative of all the data digits having been received, then the data digits are output as valid credit card account details at output 32. The other criteria may be that there are no following non-zero digits or that a final digit has been recognised. These other criteria ensure that the data is not curtailed prematurely because the checksum of a part sequence of the data digits is zero. Using more than one digit for the checksum reduces the possibility that it will be zero at any other stage than at the end of the data digit sequence. If the checksum is not zero, then the reference digit processor 26 recomputes the reference digit from the now larger sequence of digits which has been received. The process as previously described is continued until the checksum processor identifies that the checksum is zero, and the other criteria are satisfied, an uncorrectable error has been flagged, or a timer control 34 operates to request retransmission of the entire sequence. The timer control 34 may be a down-counter which is reset to a predetermined value when the DTMF demodulator starts outputting hexademical digits to the store 22. The zero count can then be used as an output signal to request retransmission of the entire sequence and reset the contents of the store to zero.

An algebraic parity check code, which is to compute the check and reference digits and correct the errors will now be described in more detail. It will be appreciated that this is only one example of a suitable code for this purpose and that other similar codes may be used which use more check digits. In the following, the data digits are represented as D1, D2, ... D50, with the digits which are unused for the purposes of the account details being set to zero, the one checksum digit is represented as C1 and the check digits as P1, P2 and P3. The hexademical digits C1, P1, P2 and P3 are calculated as follows:

$$C1 = \sum_{i=1}^{i=50} Di \quad (\text{Mod } 16)$$

$$P1 = -\{C1 + D3 + D6 + D9 + \ldots + D48\} \quad (\text{Mod } 16)$$

$$P2 = -\{D1 + D4 + D7 + D10 + \ldots + D49\} \quad (\text{Mod } 16)$$

$$P3 = -\{D2 + D5 + D8 + D11 + \ldots + D50\} \quad (\text{Mod } 16)$$

It will be noted that the data digits D1 to D50 have been separated into three interleaved subsequences in the computation of the check digits P1 to P3.

The data digits are assembled in the assembler 10 into the sequence P1, P2, P3, C1, D1, D2, D3, D4, ... D48, D50, if no preamble is to be used. If a preamble isused, then it is immediately followed by some of the data digits so that the break between the preamble and the block of information data can readily be recognised since at least the initial data digits will never have the hexademical values A to F. In this case the digits P1, P2, P3 and C1 are embedded in a relatively early part of the sequence so that processing can begin at the receiver before the complete data block has been transmitted. It is not necessarily that the checksum and check digits be transmitted as a block together and, if desired, they may be intermixed with the data digits.

At the receiver, the three reference digits, Q1, Q2, Q3 are calculated as follows:

$$Q1 = -\{P1 + C1 + D3 + D6 + D9 + \ldots\} \quad (\text{Mod } 16)$$

$$Q2 = -\{P2 + D1 + D4 + D7 + D10 + \ldots\} \quad (\text{Mod } 16)$$

$$Q3 = -\{P3 + D2 + D5 + D8 + D11 + \ldots\} \quad (\text{Mod } 16)$$

If all the data digits have been received and there are no missing digits, it will be appreciated that all three reference digits will be zero. In this event, no error correction is necessary. However, the error correction processor 28 identifies any missing digit in the subsequence used to calculate reference digit Q1 and sets it equal to Q1. If there is a further missing digit beyond the first missing digit in the subsequence used to calculate Q1 and this is not followed by yet further missing digits, as in the case of the presence of unused digits at the end of the sequence, then an uncorrectable error signal is sent to the uncorrectable error flag processor 24. The error correction processor 28 repeats the same process for the two subsequences from which reference digits Q2 and Q3 are calculated. In this way up to three missing digits can be corrected provided that each falls in a different subsequence. Therefore, this error correcting code can correct a burst of three errors since this will necessarily mean that each missing digit will fall in a different subsequence. Other patterns of errors can be corrected provided that no two missing digits fall in the same subsequence. All zeros at the ends of the subsequences are ignored until and if they are followed by a valid data digit which would identify them as missing digits rather than as unused digits transmitted as zeros. When each of the subsequences used to calculate the reference digits has a zero or missing digit at the end, it is likely that transmission of information digits is completed within the block. Therefore, at this stage the checksum processor 30 should, when computing the sum of all the then received data digits, produce a value modulo 16 which is equal to C1. If this is the case, then the data digits are output at data output 32.

If any of the reference digits are not zero when there is no identified missing digit in the whole sequence, or the checksum digit does not correspond to the sum of the data digits, this is probably indicative of one of the transmitted data digits having been demodulated incorrectly by the DTMF demodulator 20. This situation is not correctable and the retransmission of the entire sequence will be requested as a result of the output signal of the timer control 34 after a predetermined period of time sufficient for the complete block of 50 information digits to be received.

As an example let us consider the situation where we want to send the sequence of data digits 463982192. Then:

$$C1 = 4+6+3+9+8+2+1+9+2 \pmod{16} = C \text{ hexademical.}$$

$$P1 = -\{C + 3 + 2 + 2\} \pmod{16} = D$$

$$P2 = -\{4 + 9 + 1\} \pmod{16} = 2$$

$$P3 = -\{6 + 8 + 9\} \pmod{16} = 9$$

Therefore, the following sequence is transmitted, in this case with the 3 check digits followed by the checksum digit and then followed by the data digits, resulting in: D29C463982192.

Suppose we receive the following sequence, in which x represents a missing digit: D29xx63982192. The reference digits are calculated as follows

$$Q1 = -\{D + 0 + 3 + 2 + 2\} \pmod{16} = C$$

$$Q2 = -\{2 + 0 + 9 + 1\} \pmod{16} = 4$$

$$Q3 = -\{9 + 6 + 8 + 9\} \pmod{16} = 0$$

Since there is only one missing digit in each of the subsequences used to calculate the reference digits Q1 and Q2, each of these missing digits is set to the corresponding reference digit. Therefore, C1=12 and D1=4. There are no missing digits in the subsequence used to calculate the third reference digit, Q3. Since the value of Q3=0 then this provides an indication that all the demodulation digits in that subsequence are valid. The checksum processor compares C with the sum of the data digits and, since they correspond, the data digits D1 to D9 are output.

As only nine digits were required to be sent, no further digits are sent. This results in the next processing of the received digits having an extra missing digit in the subsequence for calculating Q1. This does not result in an uncorrectable error flag because it is the last digit in the sequence. Since the checksum produces a valid output, the assumption that the remaining digits are zero is valid, and the end of the sequence can be identified.

This type of algebraic parity check code enables credit card account details to be conveniently sent on a cellular radio telephone link with a high degree of reliability. The number of uncorrectable errors that will be found in practice is relatively low and therefore the user will be able to complete his call. This is significantly advantageous over systems which request retransmission of the credit account details either manually or automatically if a digit is missed. This would produce an unacceptably long delay before the call proper was allowed to proceed, if used on a cellular radio telephone link.

It will be appreciated that the processing required for implementing the code both in the telephone and receiver can readily be carried out by a suitably programmed microprocessor with associated memories.

CLAIMS

1. A credit card payphone for use in a cellular radio telecommunications system, comprising a cellular radio telephone, means for inputting details of a caller's credit card account in the form of a series of data digits, means for computing a checksum comprising k digits representing the sum modulo n^k of the data digits (where k is any positive integer), and at least three further check digits, each check digit being computed as the complement of the modulo n sum of a subset of the data digits and the digit(s) of the checksum, each data digit and digit of the checksum being included in at least one check digit sum, and means for transmitting a sequence of digits including said data digits, said checksum and said at least three check digits using a DTMF modulator adapted to transmit n different frequency combinations.

2. A credit card payphone as claimed in claim 1 wherein k is 1.

3. A receiver for use in a cellular radio telecommunication system in conjunction with a credit card payphone as claimed in claim 1 or 2, the receiver comprising a DTMF demodulator for decoding the received digits, means for recognising and flagging missing digits, means for computing from said received digits at least three reference digits, where each reference digit is the complement modulo n of the sum of a respective check digit and the sum of the received digits corresponding to the digits used to compute said check digit, said reference digits being calculated using a zero in place of any missing digit, means for using said reference digits to correct no more than one missing digit in the sum from which each reference digit is computed, and means for outputting the received data digits including any corrected data digits if and only if there is no more than one missing digit in the sum for each reference digit and the received or corrected checksum corresponds to the sum of the data digits modulo n^k.

4. A credit card payphone system for use in a cellular radio telecommunication system,